OF THE CAUSE OF *ATTRACTION* BY Suction, A PARADOX.

By the Honourable
ROBERT BOYLE,
Fellow of the *Royal Society*.

LONDON,
Printed by *William Godbid*, and are to be Sold by *Moses Pitt*, at the *Angel* over against the little North Door of St. *Paul's* Church. 1674.

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PREFACE.

HAving about twelve years ago ſummarily expreſt and publiſh'd my Opinion of the Cauſe of Suction, and a while before or after brought to the Royal Society the Glaſs Inſtrument I employ'd to make it out; I deſiſted for ſome time to add any thing about a Problem, that I had but occaſionally handled: Only, becauſe the Inſtrument I mention'd in my Examen of Mr. Hobbes's Opinion, and afterwards us'd at Greſham-College, was difficult enough to be well made, and not to be procur'd ready made, I did for the ſake of ſome Virtuoſi, that were curious of ſuch things, deviſe a ſlight and eaſily made Inſtrument, deſcrib'd in the following Tract, Chap. 4th, in which the chief Phænomena, I ſhew'd before the Society, were eaſily producible. But afterwards the miſtakes and erroneous Opinions,

that, in Print as well as in Discourse, I met with, even among Learned Men, about Suction, *and the Curiosity of an Ingenious Person, engaged me to resume that Subject and treat of it, as if I had never before meddled with it, for the reason intimated in the beginning of the insuing Paper. And finding upon the review of my later* Animadversions *on Mr.* Hobbes's Problemata de Vacuo, *that some passages of this Tract are referr'd to there; I saw my self thereby little less than engaged to annex that Discourse to those Animadversions. And this I the rather consented to, because it contains some Experiments, that I have not elsewhere met with, which, together with some other parts of that* Essay, *may, I hope, prove of some use to illustrate and confirm our Doctrine about the Weight and Spring of the Air, and supply the less experienced than ingenious Friends to our Hypothesis with more grounds of answering the later Objections of some Learned Men, against whose endeavours I perceive it will be useful to employ variety of Experiments and other Proofs to*

vince the same Truth; that some or other *of these may meet with those Arguments or evasions with which they strive to elude the force of* the rest.

The Title of the following Essay may sufficiently keep the Reader from expecting to find any other kind of Attraction *discours'd of, than that which is made by* Suction. *But yet thus much I shall here intimate in general, that I have found by Trials purposely made, that the Examples of* Suction *are not the only noted ones of* Attraction, *that may be reduced to* Pulsion.

OF

OF THE

CAUSE

OF

Attraction by Suction,

A

PARADOX.

Chap. I.

I Might, *Sir*, save my self some trouble in giving you that account you desire of me about *Suction*, by referring you to a passage in the *Examen*, I long since writ, of Mr. *Hobbes*'s *Dialogus Physicus de Natura Aeris*, if I knew you had those two Books lying by you. But because I suspect, that my *Examen*

may not be in your hands, since 'tis almost out of Print, and has not for some years been in my own; and because I do not so well remember, after so long a time, the particulars that I writ there, about Suction, as I do in general, that the *Hypothesis* I proposed, was very incidentally and briefly discours'd of, upon an occasion ministred by a wrong Explication given of Suction by Mr. *Hobbes*, I shall here decline referring you to what I there writ; and proposing to you those thoughts about Suction, that I remember I there pointed at, I shall annex some things to illustrate and confirm them, that would not have been so proper for me to have insisted on in a short and but occasional Excursion.

And I should immediately proceed to what you expect from me, but that *Suction* being generally look'd upon as a kind of *Attraction*, it will be requisite for me to premise something about *Attraction* it self. For, besides that the Cause of it, which

I here diſpute not of; is obſcure, the very Nature and Notion of it is wont by Naturaliſts to be either left untouch'd, or but very darkly deliver'd, and therefore will not be unfit to be here ſomewhat explain'd.

How general and ancient ſoever the common Opinion may be, that *Attraction* is a kind of Motion quite differing from *Pulſion*, if not alſo oppoſite to it, yet I confeſs, I concur in opinion, though not altogether upon the ſame grounds, with ſome modern Naturaliſts, that think Attraction a *Species* of Pulſion. And at leaſt among inanimate Bodies I have not yet obſerved any thing, that convinces me, that Attraction cannot be reduced to Pulſion; for, theſe two ſeem to me to be but extrinſical denominations of the ſame Local Motion, in which, if a moved Body *precede* the Movent, or tend to acquire a greater diſtance from it, we call it *Pulſion*; and if, upon the ſcore of the Motion, the ſame Body *follow* the Movent or approach to it, we call it

Attraction. But this difference may consist but in an *accidental* respect, which does not *Physically* alter the nature of the Motion, but is founded upon the respect, which the Line, wherein the Motion is made, happens to have to the situation of the Movent. And that which seems to me to have been the chief cause of mens mistaking Attraction for a motion opposite to Pulsion, is, that they have look'd upon both the moving and moved Bodies, in too popular and superficial a manner, and consider'd in the *Movent* rather the situation of the conspicuous and more bulky part of the Animal or other Agent, than the situation of that part of the Animal, or Instrument, that does immediately impress that motion upon the *Mobile*.

For those that attentively heed this, may easily take notice, that some part of that Body, or of the Instrument, which by reason of their conjunction in this operation is to be look'd on but as making one with it, is really placed

placed behind ſome part of the Body to be drawn, and therefore cannot move outwards it ſelf without thruſting that Body forward. This will be eaſily underſtood, if we conſider, what happens when a Man draws a Chain after him; for, though his Body do *precede* the Chain, yet his finger or ſome other part of the hand, wherewith he draws it, has ſome part or other that reaches *behind* the fore part of the firſt Link, and the hinder part of this Link comes behind the anteriour part of the ſecond Link, and ſo each Link has one of its parts placed behind ſome part of the Link next after it, 'till you come to the laſt Link of all. And ſo, as the finger, that is in the firſt Link, cannot move forwards but it muſt thruſt on that Link, by this *ſeries* of Truſions the whole Chain is moved forwards, and if any other Body be drawn by that Chain, you may perceive, that ſome part of the laſt Link comes behind ſome part of that Body, or of ſome intervening Body,

which, by its cohesion with it, ought in our present case to be consider'd as part of it. And thus *Attraction* seems to be but a *Species* of *Pulsion*, and usually belongs to that kind of it, which, for distinctions sake, is called *Traction*, by which we understand that kind of Pulsion, wherein the Movent goes along with the moved Body without quitting it whilst the progress lasts, as it happens, when a Gardiner drives his Wheel-barrow before him without letting go his hold of it.

But I must not here dissemble a difficulty, that I foresee may be speciously urged against this account of Attraction. For it may be said, that there are Attractions, where it cannot be pretended, that any part of the *Attrahent* comes behind the *Attracted* Body, as in *Magnetical* and *Electrical* Attractions, and in that which is made of Water, when 'tis drawn up into Springs and Pumps.

I need not tell you, that you know so well, as that partly the *Cartesians*, and

and partly other Modern Philoſophers, have recourſe on this occaſion either to *ſcrewed* Particles and other Magnetical Emiſſions, to explicate *Phænomena* of this kind. And, according to ſuch *Hypotheſes*, one may ſay, that many of theſe Magnetical and Electrical *Effluvia* come behind ſome parts of the attracted Bodies, or at leaſt of the little ſolid Particles, that are as it were the Walls of their Pores, or procure ſome diſcuſſion of the Air, that may make it thruſt the Moveable towards the Loadſtone or Amber, *&c.* But if there were none of theſe, nor any other ſubtil Agents that cauſe this Motion by a real, though unperceived, Pulſion; I ſhould make a diſtinction betwixt other Attractions and theſe, which I ſhould then ſtile *Attraction by Inviſibles.* But, whether there be really any ſuch in Nature, and why I ſcruple to admit things ſo hard to be conceived, may be elſewhere conſider'd. And you will, I preſume, the freelier allow me this liberty, if, (ſince

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in this place 'tis proper to do it,) I shew you, that in the last of the instances I formerly objected (that of the drawing up of Water into the Barrel of a Syringe,) there is no true Attraction of the Liquor made by the external Air. I say then, that by the ascending Rammer, as a part of which I here consider the obtuse end, Plug, or Sucker, there is no Attraction made of the contiguous and subjacent Water, but only there is room made for it, to rise into, without being expos'd to the pressure of the superiour Air. For, if we suppose the whole Rammer to be by Divine Omnipotence annihilated, and consequently uncapable of exercising any Attraction, yet, provided the superiour Air were kept off from the Water by any other way as well as 'twas by the Rammer, the Liquor would as well ascend into the Cavity of the Barrel, since, (as I have elsewhere abundantly proved,) the surface of the Terraqueous Globe being continually press'd on by the incumbent

bent Air or Atmosphere, the Water must be by that pressure impell'd into any cavity here below, where there is no Air to resist it, as by our Supposition there is not in the Barrel of our Syringe, when the Rammer, or whatever else was in it, had been annihilated. Which Reasoning may be sufficiently confirm'd by an Experiment, whereby I have more than once shewn some curious persons, that, if the external Air, and consequently its pressure, be withdrawn from about the Syringe, one may pull up the Sucker as much as he pleases, without drawing up after it the subjacent Water. In short, let us suppose, that a Man standing in an inner room does by his utmost resistance keep shut a Door, that is neither lock'd nor latch'd, against another, who with equal force endeavours to thrust it open. In this case, *as* if one should forcibly pull away the first Man, it could not be said, that this Man, by his recess from the Door he endeavoured to

press

preſs outwards, did truely and properly draw in his Antagoniſt, though upon that receſs the coming in of his Antagoniſt would preſently enſue; ſo it cannot properly be ſaid, that by the aſcent of the Rammer, which diſplaces the ſuperiour Air, either the Rammer it ſelf, or the expelled Air, does properly *attract* the ſubjacent Water, though the ingreſs of that Liquor into the Barrel does thereupon neceſſarily enſue. And that, as the Compariſon ſuppoſes, there is a preſſure of the ſuperiour Air againſt the upper part of the Sucker, you may eaſily perceive, if having well ſtopt the lower orifice of the Syringe with your finger, you forcibly draw up the Sucker to the top of the Barrel. For if then you let go the Rammer, you will find it impell'd downwards by the incumbent Air with a notable force.

CHAP.

Chap. II.

HAving thus premis'd something in general about the Nature of *Attraction*, as far as 'tis necessary for my present design; it will be now seasonable to proceed to the consideration of that kind of Attraction, that is employed to raise Liquors, and is by a distinct Name called *Suction*.

About the Cause of this there is great contention between the New Philosophers, as they are stiled, and the Peripateticks. For the Followers of *Aristotle*, and many Learned Men that in other things dissent from him, ascribe the ascension of Liquors upon *Suction* to Natures abhorrence of a *Vacuum*. For, say they, when a Man dips one end of a Straw or Reed into stagnant Water, and sucks at the other end, the Air contain'd in the cavity of the Reed passes into that

of

of his Lungs, and consequently the Reed would be left empty, if no other Body succeeded in the place it deserts; but there are only (that they take notice of,) two Bodies that can succeed, the Air and the (grosser Liquor) the Water; and the Air cannot do it, because of the interposition of the Water, that denies it access to the immers'd orifice of the Reed, and therefore it must be the Water it self, which accordingly does ascend to prevent a *Vacuum* detested by Nature.

But many of the Modern Philosophers, and generally all the *Corpuscularians*, look upon this *Fuga Vacui* as but an imaginary Cause of *Suction*, though they do it upon very differing grounds. For, the *Atomists*, that willingly admit of Vacuities, properly so called, both within and without our World, cannot think that Nature hates or fears a *Vacuum*, and declines her usual course to prevent it: And the *Cartesians*, though they do, as well as the *Peripateticks*,

deny

deny that there is a *Vacuum*, yet since they affirm not only, that there is none *in rerum Natura*, but that there *can be* none, because what others call an empty Space having three Dimensions, hath all that they think belonging to the Essence of a *Body*, they will not grant Nature to be so indiscreet, as to strain her self to prevent the making of a thing that is impossible to be made.

The *Peripatetic* Opinion about the Cause of Suction, though commonly defended by the Schools, as well Modern as Ancient, supposes in Nature such an abhorrence of a *Vacuum*, as neither has been well proved, nor does well agree with the lately discover'd Phænomenon of *Suction*. For, according to their *Hypothesis*, Water and other Liquors should ascend upon Suction to any hight to prevent a *Vacuum*, which yet is not agreeable to experience. For I have carefully tryed, that by pumping with a Pump far more stanch than those that are usually made, and indeed as well clos'd

clos'd as we could possibly bring it to be, we could not by all our endeavours raise Water by Suction to above *36 ½ foot. The *Torricellian* Exp^t shews, that the weight of the Air is able to sustain, and some of our Experim^ts shew, 'tis able to raise a Mercurial Cylinder equal in weight to as high a Cylinder of Water as we were able to raise by pumping. For Mercury being near 14 times as heavy as Water of the same bulk, if the weight of the Air be equivalent to that of a Mercurial Cylinder of 29 or 30 Inches, it must be able to counterpoise a Cylinder of Water near fourteen times as long, that is, from thirty four to near thirty six foot. And very disagreeable to the common *Hypothesis*, but consonant to ours, is the Experiment that I have more than once tryed, and I think elsewhere deliver'd, namely, That, if you take a Glass Pipe of about three foot long, and, dipping one end of it in Water, suck at the other, the Water will be suddenly made

*See Cont. of Phys. Mech. Exp. the 15th Exp.

made to flow briskly into your mouth: But, if inſtead of Water you dip the lower end into Quick-ſilver, though you ſuck as ſtrongly as ever you can, provided that in this caſe, as in the former, you hold the Pipe upright, you will never be able to ſuck up the Quickſilver near ſo high as your mouth; ſo that if the Water aſcended upon Suction to the top of the ſame Pipe, becauſe elſe there would have been a *Vacuum* left in the cavity of it, why ſhould not we conclude, that, when we have ſuckt up the Quickſilver as ſtrongly as we can, as much of the upper part of the Tube as is deſerted by the Air, and yet not fill'd by the Mercury, admits, in part at leaſt, a *Vacuum*, (as to Air) of which conſequently Nature cannot reaſonably be ſuppos'd to have ſo great and unlimited an abhorrency, as the *Peripateticks* and their Adherents preſume. Yet I will not determine, whether there be any more than many little Vacuities, or Spaces devoid of Air, in the Cavity,

so called, of the Pipe unfill'd by the Mercury, (so that the whole Cavity is not one entire empty Space,) it being sufficient for my purpose, that my Experiment affords a good Argument *ad hominem* against the *Peripateticks*, and warrants us to seek for some other Cause than the *fuga Vacui*, why a much stronger Suction than that, which made Water ascend with ease into the Suckers mouth, will not also raise Quicksilver to the same height or near it.

Those Modern Philosophers that admit not the *fuga Vacui* to be the Cause of the raising of Liquors in Suction, do generally enough agree in referring it to the action of the Suckers *thorax*. For, when a Man endeavours to suck up a Liquor, he does by means of the Muscles enlarge the cavity of his Chest, which he cannot do but at the same time he must thrust away those parts of the ambient Air that were contiguous to his Chest, and the displaced Air does, according to some Learned Men,

(therein, if I mistake not, Followers of *Gassendus*,) compress the contiguous Air, and that the next to it, and so outwards, 'till the pressure, successively passing from one part of the Air to the other, arrive at the surface of the Liquor; and all other places being as to sense full, the impell'd Air cannot find place but by thrusting the Water into the room made for it in the Pipe by the recess of the Air that pass'd into the Suckers lungs. And they differ'd not much from this Explication, that, without taking in the compression of the ambient Air made by the *thorax*, refer the Phænomenon to the propagated motion or impulse, that is impress on the Air displac'd by the *thorax* in its dilatation, and yet unable to move in a World perfectly fill'd, as they suppose ours to be, unless the Liquor be impell'd into as much of the cavity of the Pipe, as fast as 'tis deserted by the Air that is said to be suck'd up. But though I readily confess this Explication to be ingenious, and such as I

wonder not they ſhould acquieſs in, who are acquainted but with the long known and obvious *Phænomena* of Suction; and though I am not ſure, but that in the moſt familiar caſes the Cauſes aſſign'd by them may contribute to the Effect, yet, preſerving for *Carteſius* and *Gaſſendus* the reſpect I willingly pay ſuch great Philoſophers, I muſt take the liberty to tell you, that I cannot acquieſs in their Theory. For I think, that the Cauſe of *Suction*, they aſſign, is in many caſes not neceſſary, in others, not ſufficient. And *firſt*, as to the Condenſation of the Air by the dilatation of the Suckers Cheſt; when I conſider the extent of the ambient Air, and how ſmall a compreſſion no greater an expanſion than that of the *Thorax* is like to make, I can ſcarce think, ſo ſlight a condenſation of the free Air can have ſo conſiderable an operation on the ſurface of the Liquor to be rais'd, as the *Hypotheſis* I examin requires: And that this impulſe of the Air by a Suckers

dilated

dilated *Thorax*, though it be wont to accompany the aſcenſion of the water procured by Suction, yet is not of abſolute neceſſity to it, will, I preſume, be eaſily granted; if it can be made out, that even a propagated *Pulſion*, abſtracted from any Condenſation of Air, is not ſo neceſſarily the Cauſe of it, but that the Effect may be produc'd without it. For ſuppoſe, that by Divine Omnipotence ſo much Air as is diſplac'd by the *Thorax* were annihilated; yet I ſee not, why the Aſcenſion of the Liquor ſhould not enſue. For, when a Man begins to ſuck, there is an *Æquilibrium*, or rather Æquipollency *between* the preſſure, which the Air, contained in the Pipe, (which is ſhut up with the preſſure of the Atmoſphere upon it,) has, by virtue of its *Spring*, upon that part of the ſurface of the water that is environ'd by the ſides of the Pipe, *and* the preſſure which the Atmoſpherical Air has, by virtue of its *weight*, upon all the reſt of the ſurface of the ſtagnant water; ſo that,

when by the dilatation of the Suckers *Thorax*, the Air within the cavity of the Pipe comes to be rarified, and consequently loose of its *Spring*, the *weight* of the external Air continuing in the mean time the same, it must necessarily happen, that the Spring of the internal Air will be too weak to compress any longer the gravitation of the external, and consequently, that part of the surface of the stagnant water, that is included in the Pipe, being less pres'd upon, than all the other parts of the same surfaces must necessarily give way, where it can least resist, and consequently be impell'd up into the Pipe, where the Air, having had its Spring weakened by expansion, is no longer able to resist, as it did before. This may be illustrated by somewhat varying an Instance already given, and conceiving, that within a Chamber three Men thrust all together with their utmost force against a Door, (which we suppose to have neither Bolt nor Latch) to keep it shut, at

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the same time the three other Men have just equal strength, and imploy their force to thrust it open. For though, whilst their opposite endeavours are equal, the Door will continue to be kept shut, yet if one of the three Men within the Room should go away, there will need no new force, nor other accession of strength to the three Men, to make them prevail and thrust open the Door against the resistance of those that endeavour'd to keep it shut, who are now but two.

And here (upon the by) you may take notice, that, to raise water in Suction, there is no necessity of any rarified and forcibly stretch'd Rope, as 'twere, of the Air, to draw up the subjacent water into the Pipe, since the bare debilitation of the Spring of the included Air may very well serve the turn. And though, if we should suppose the Air within the Pipe to be quite annihilated, it could not be pretended (since it would not have so much as Existence) that it exer-

ciſes an attractive Power; yet in this caſe the water would aſcend into the Pipe, without the aſſiſtance of Natures imaginary Abhorrence of a *Vacuum*, but by a Mechanical Neceſſity, plainly ariſing from this, that there would be a preſſure of the incumbent Atmoſphere upon the reſt of the ſurface of the ſtagnant water, and no preſſure at all upon that part of the ſurface that is within the Pipe, where conſequently there could be no reſiſtance made to the aſcenſion of the water, every where elſe ſtrongly urg'd by the weight of the incumbent Air.

I ſhall add on this occaſion, that, to ſhew ſome inquiſitive Men, that the weak reſiſtance within a Veſſel, that had but one orifice expos'd to the water, may much more contribute to the aſcenſion of that Liquor into the Veſſel, than either the compreſſion or the continued or reflected impulſe of the external Air, I thought fit to produce a Phænomenon, which by the Beholders was without ſcruple

judg'd an Effect of Suction, and yet could not be aſcrib'd to the Cauſe of Suction, aſſign'd by either of the Sects of Philoſophers I diſſent from. The Experiment was this: By a way, elſewhere deliver'd, the long neck of a Glaſs-bubble was ſeal'd up, and almoſt all the Air had been by Heat driven out of the whole cavity of the Bubble or Vial, and then the Glaſs was laid aſide for ſome hours, or as long as we pleas'd; afterwards the ſeal'd *apex* of the neck was broken off under water: I demand now of a *Peripatetic*, whether the Liquor ought to be ſuck'd or drawn into the cavity of the Glaſs, and why: if he ſays, as queſtionleſs he will, that the water would be attracted to hinder a *Vacuum*, he would thereby acknowledge, that, 'till the Glaſs was unſtopt under water, there was ſome empty ſpace in it; for, 'till the ſealed end was broken off, the water could not get in, and therefore, if the *fuga vacui* had any thing to do in the aſcenſion, the Liquor muſt riſe, not to

prevent an empty space, but to fill one that was made before. Nor does our Experiment much more favour the other Philosophers, I dissent from: For in it there is no dilatation made of the sides of the Glass, as in ordinary Suction there is made of the *Thorax*, but only there is so much Air driven out of the cavity of the Bubble, into whose room since neither common Air nor Water is permitted to succeed, it appears not, how the propagated and returning impulse, or the Circle of Motion, as to common Air and Water, does here take place. And then I demand, what becomes of the Air, that has been by heat driven out, and is by the Hermetical Seal kept out of the cavity of the Bubble? If it be said, that it diffuses it self into the ambient Air, and mingles with it, that will be granted which I contended for, that so little Air as is usually displac'd in Suction cannot make any considerable compression of the free ambient Air; for, what can one Cubic Inch

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of Air, which is ſometimes more than one of our Glaſſes contains, do, to the condenſation ſo much as of all the Air in the Chamber, when the expell'd Corpuſcles are evenly diſtributed among thoſe of the ambient. And how comes this inconſiderable condenſation to have ſo great an effect in every part of the room, as to be able there to impel into the Glaſs as much water in extent as the whole Air that was driven out of the cavity of it? But if it be ſaid, that the expell'd Air condens'd only the contiguous or very neighbouring Air, 'tis eaſie to anſwer, that 'tis no way probable, that the expell'd Particles of the Air ſhould not by the differing motions of the ambient Air be quickly made to mingle with it, but ſhould rather wait (which if it did we ſometimes made it do for many hours) 'till the Veſſels whence 'twas driven out were unſtopp'd again. But, though this could probably be pretended, it cannot truly be aſſerted. For if you carry the ſeal'd Glaſs quite out of the room

room or houſe, and unſtop it at ſome other place, though two or three miles diſtant; the aſcenſion of the water will, (as I found by tryal) nevertheleſs inſue; in which caſe I preſume, it will not be ſaid, that the Air, that was expell'd out of the Glaſs, and condens'd the contiguous or near contiguous Air, attended the Bubble in all its motions, and was ready at hand to impel-in the water, as ſoon as the ſeal'd *apex* of the Vial was broken off. But I doubt not, but moſt of the Embracers of the Opinion I oppoſe, being Learned and Ingenuous Perſons, if they had been acquainted with theſe and the like *Phænomena*, would rather have changed their Opinion about *Suction*, than have gone about to defend it by ſuch Evaſions, which I ſhould not have thought worth propoſing, if I had not met with Objections of this nature publickly maintain'd by a Learned Writer, on occaſion of the Air's ruſhing into the exhauſted *Magdenburgic* Engine. But as in our Expe-

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riment theſe Objections have no place, ſo in our *Hypotheſis* the Explication is very eaſie, as will anon be intimated.

CHAP. III.

HAving thus ſhewn, that the Aſcenſion of Water upon Suction may be caus'd otherwiſe than by the Condenſation or the propagated Pulſion of Air contiguous to the Suckers *Thoracæ*, and thruſt out of place by it, it remains that I ſhew, (which was one of the two things I chiefly intended,) that there may be Caſes wherein the Cauſe, aſſign'd in the *Hypotheſis* I am examining, will not have place. But this will be better underſtood, if, before I proceed to the proof of it, I propoſe to you the thoughts, I had many years ſince, and do ſtill retain, about the Cauſe of the Aſcenſion of Liquors in Suction.

To clear the way to the right underſtanding

derſtanding of the enſuing Diſcourſe, it will not be amiſs here to premiſe a ſummary intimation of ſome things that are ſuppos'd in our *Hypotheſis*.

We ſuppoſe then *firſt*, without diſputing either the Exiſtence or the nature of Elementary Air, that the Common Air we breath in, and which I often call Atmoſpherical Air, abounds with Corpuſcles not devoid of Weight, and indowed with Elaſticity or Springineſs, whereby the lower parts, compreſt by the weight of the upper, inceſſantly endeavour to expand themſelves, by which expanſion, and in proportion to it, the Spring of the Air is weaken'd, (as other Springs are wont to be) the more they are permitted to ſtretch themſelves.

Next, we ſuppoſe, that the Terraqueous Globe, being environ'd with this gravitating and ſpringy Air, has its ſurface and the Bodies plac'd on it preſt by as much of the Atmoſphere as either perpendicularly leans on them, or can otherwiſe come to bear upon

upon them. And this preſſure is by the *Torricellian* and other Experiments found to be equivalent to a perpendicularly erected Cylinder of about twenty nine or thirty Inches of Quickſilver, (for the height is differing, as the gravity of the Atmoſphere happens to be various.)

Laſtly, we ſuppoſe, that, Air being contain'd in a Pipe or other hollow Body that has but one orifice open to the free Air, if this orifice be Hermetically ſeal'd, or otherwiſe (as with the mouth of one that ſucks) clos'd, the now included Air, whilſt it continues without any farther expanſion, will have an elaſticity equivalent to the weight of as much of the outward Air as did before preſs againſt it. For, if the weight of the Atmoſphere, to which it was then expos'd, had been able to compreſs it further, it would have done ſo, and then the cloſing of the orifice, at which the internal and external Air communicated, as it fenc'd the included Air from the preſſure

of the incumbent, ſo it hindred the ſame included Air from expanding it ſelf; ſo that, as it was ſhut up with the preſſure of the Atmoſphere upon it, that is in a ſtate of as great compreſſion as the weight of the Atmoſphere could bring it to, ſo, being ſhut up and thereby kept from weakening that preſſure by expanſion, it muſt retain a Springineſs equipollent to the preſſure 'twas expos'd to before, which (as I juſt now noted) was as great as the weight of the incumbent Pillar of the Atmoſphere could make it. But if, as was ſaid in the firſt Suppoſition, the included Air ſhould come to be dilated or expanded, the Spring being then unbent, its Spring, like that of other elaſtical Bodies, would be debilitated anſwerably to that expanſion.

To me then it ſeems, that, ſpeaking in general, Liquors are upon Suction raiſed into the cavities of Pipes and other hollow Bodies, when, and ſo far as, there is a leſs preſſure

on

on the ſurface of the Liquor in the cavity, than on the ſurface of the external Liquor that ſurrounds the Pipe, *whether* that preſſure on thoſe parts of the external Liquor, that are from time to time impell'd up into the orifice of the Pipe, proceed from the weight of the Atmoſphere, *or* the propagated compreſſion or impulſe of ſome parts of the Air, *or* the Spring of the Air, *or* ſome other Cauſe, as the preſſure of ſome other Body quite diſtinct from Air.

Upon the general view of this *Hypotheſis*, it ſeems very conſonant to the Mechanical Principles. For, if there be on the differing parts of the ſurface of a fluid Body unequal preſſures, 'tis plain, as well by the nature of the thing, as by what has been demonſtrated by *Archimedes*, and his Commentators, that the greater force will prevail againſt the leſſer, and that that part of the waters ſurface muſt give way, where it is leaſt preſt. So that that, wherein the *Hypotheſis* I venture to propoſe to you,

differs from that which I diſſent from, is not, that mine is leſs Mechanical; but *partly* in this, that, whereas the *Hypotheſis*, I queſtion, ſuppoſes a neceſſity of the protruſion of impulſe of the Air, mine does not require that ſuppoſition, but, being more general, reaches to other ways of procuring the Aſcenſion of Liquors, without raiſing them by the impulſe of the Air; and *partly*, and indeed chiefly, in that the *Hypotheſis*, I decline, makes the Cauſe of the Aſcenſion of Liquors to be only the increaſed preſſure of the Air external to the pipe; and I chiefly make it to depend upon the diminiſhed preſſure of the Air within the pipe, on the ſcore of the expanſion 'tis brought to by Suction.

To proceed now to ſome Experiments that I made in favour of this *Hypotheſis*, I ſhall begin with that which follows:

We took a Glaſs-pipe bended like a Syphon, but ſo that the ſhorter legg was as parallel to the longer as we could

could get it made, and was Hermetically seal'd at the end: Into this Syphon we made a shift (for 'tis not very easie) to convey water, so that the crooked part being held downwards, the liquor reach'd to the same height in both the leggs, and yet there was about an Inch and half of uncompress Air shut up in the shorter legg. This little Instrument (for 'twas but about fifteen Inches long) being thus prepar'd, 'tis plain, that according to the *Hypothesis* I dissent from, there is no reason, why the water should ascend upon Suction. For, though we should admit, that the external Air were considerably compress, or received a notable impulse, when the Suckers chest is enlarged; yet in our case that compression or protrusion will not reach the surface of the water in the shorter legg, because it is there fenc'd from the action of the external Air by the sides of the Glass, and the Hermetical Seal at the top. And yet, if one suck'd strongly at the open orifice in the

longer legg, the water in the ſhorter would be depreſt, and that in the longer aſcended at one ſuck about an Inch and half: Of which the reaſon is clear in our *Hypotheſis*. For, the Spring of the included Air, together with the weight of the water in the ſhorter legg, and the preſſure of the Atmoſpherical Air, aſſiſted by the weight of the liquor in the longer legg, counter-ballanced one another before the Suction began: But, when afterwards upon Suction the Air in the longer legg came to be dilated and thereby weaken'd, 'twas render'd unable to reſiſt the undiminiſh'd preſſure of the Air included in the ſhorter legg, which conſequently expanding it ſelf by vertue of its Elaſticity, depreſt the contiguous water, and made it proportionably riſe in the oppoſite legg, 'till by the expanſion its Spring being more and more weaken'd, it arrived at an equipollency with the gravitation or preſſure of the Atmoſphere. Which laſt clauſe contains the Reaſon, why, when the

the perſon that ſuckt had rais'd the water in the longer legg *leſs than* three Inches higher by repeated endeavours to ſuck, and that without once ſuffering the water to fall back again; he was not able to elevate the water in the longer, *ſo much as* three Inches above its firſt ſtation. And if in the ſhorter legg there was but an Inch and a quarter of ſpace left for the Air unfill'd by the water, by diverſ skilfully reiterated acts of Suction he could not raiſe the liquor in the longer legg above two Inches, becauſe by that time the Air included in the ſhorter legg had, by expanding it ſelf further and further, proportionably weaken'd its Spring, 'till at length it became as rarified, as was the Air in the cavity of the longer legg, and conſequently was able to thruſt away the water with no more force than the Air in the long legg was able to reſiſt. And by the recited tryal it appear'd, that the rarefaction uſually made of Air by Suction is not near ſo great, as one would

expect, problably because by the dilatation of the Lungs the Air, being still shut up, is but moderately rarified, and the Air in the longer legg can by them be brought to no greater degree of rarity, than that of the Air within the Chest. For, whereas the included Air in our Instrument was not expanded, by my estimate, at one suck to above the double of its former dimensions, and by divers successive sucks was expanded but from one Inch and an half to less than four Inches and an half, if the Suction could have been conveniently made with a great and stanch Syringe, the rarefaction of the Air would probably have been far greater, since in our Pneumatick Engin Air may, without heat, and by a kind of Suction, be brought to possess many hundreds of times the space it took up before. From this rarefaction of the Air in both the leggs of our Instrument proceeds another *Phænomenon*, readily explicable by our *Hypothesis*. For if, when the water was impell'd

impell'd up as high as the Suction could raise it, the Instrument were taken from the Suckers mouth, the elevated water would with violence return to its wonted station. For, the Air, in both the leggs of the Instrument, having by the Suction lost much of the Spring, and so of its power of pressing, when once the orifice of the longer legg was left open, the Atmospherical Air came again to gravitate upon the water in that legg, and the Air, included in the other legg, having its Spring debilitated by the precedent expansion, was not able to hinder the external Air from violently repelling the elevated water, 'till the included Air was thrust into the space it possess'd before the Suction, in which space it had Density and Elasticity enough to resist the pressure, that the external Air exercis'd against it through the interpos'd water.

But our *Hypothesis* about the Cause of Suction would not need to be solicitously prov'd to you by other ways,

if you had seen what I have sometimes been able to do in our Pneumatick Engin. For, there we found by tryals purposely devis'd, and carefully made, that a good Syringe being so conveyed into our Receiver, that the open orifice of the Pipe or lower part was kept under water, if the Engin were exhausted, though the handle of the Syringe were drawn up, the water would not follow it, which yet it would do if the external Air were let in again. The Reason of which is plain in our *Hypothesis*. For, the Air, that should have prest upon the surface of the stagnant water, having been pumpt out, there was nothing to impell up the water into the deserted cavity of the Syringe, as there was when the Receiver was fill'd with Air.

CHAP. IV.

BUt becauſe ſuch a conveniency as our Engin, and the *apparatus* neceſſary for ſuch Tryals are not eaſily procurable, I ſhall endeavour to confirm our *Hypotheſis* about Suction by ſubjoining ſome Experiments, that may be tryed without the help of that Engin, for the making out theſe three things:

I. *That a Liquor may be rais'd by Suction, when the preſſure of the Air, neither as it has Weight nor Elaſticity, is the Cauſe of the Elevation.*

II. *That the weight of the Atmoſpherical Air is ſufficient to raiſe up Liquors in Suction.*

III. *That in ſome caſes Suction will not be made, as, according to the Hypotheſis I diſſent from, it ſhould, although there be a dilatation of the Suckers* Thorax, *and no danger of a* Vacuum *though the Liquor ſhould aſcend.*

And

And *first*, to shew, how much the rising of Liquors in Suction depends upon the weight or pressure of the impellent Body, and how little necessity there is, where that pressure is not wanting, that, in the place deserted by the Liquor that is suck'd, there should succeed Air or some other visible Body, as the *Peripatetic* Schools would have it; to shew this, *I say*, I thought on the following Experiments. We took a Glass-pipe fit to have the *Torricellian* Experiment made with it, but a good deal longer than was necessary for that use: This Pipe being Hermetically seal'd at one end, the other end was so bent as to be reflected upwards, and make as it were the shorter legg of the Syphon as parallel as we could to the longer, so that the Tube now was shap'd like an inverted Syphon with leggs of a very unequal length. This Tube, notwithstanding its inconvenient figure, we made a shift, (for 'tis not easily done) to fill with Mercury, when 'twas in an inclin'd posture,

posture, and then erecting it, the Mercury subsided in the longer legg, as in the *Torricellian* Experiment, and attain'd to between two foot and a quarter and two foot and an half above the surface of the Mercury in the shorter legg; which in this Instrument answers to the stagnant Mercury in an ordinary *Barometer*, from which to distinguish it I have elsewhere call'd this Syphon, furnish'd with Mercury, a *Travelling Baroscope*, because it may be safely carried from place to place. Out of the shorter legg of this Tube we warily took as much Mercury as was thought convenient for what we had further to do, and this we did by such a way as to hinder any Air from getting into the deserted cavity of the longer legg, by which means the Mercurial Cylinder, (estimated as I lately mention'd) retain'd the same height above the stagnant Mercury in the shorter: The upper and clos'd part of this Travelling Baroscope you will easily grant to have been free from Common

Air,

And *first*, to shew, how much the rising of Liquors in Suction depends upon the weight or pressure of the impellent Body, and how little necessity there is, where that pressure is not wanting, that, in the place deserted by the Liquor that is suck'd, there should succeed Air or some other visible Body, as the *Peripatetic* Schools would have it; to shew this, *I say*, I thought on the following Experiments. We took a Glass-pipe fit to have the *Torricellian* Experiment made with it, but a good deal longer than was necessary for that use: This Pipe being Hermetically seal'd at one end, the other end was so bent as to be reflected upwards, and make as it were the shorter legg of the Syphon as parallel as we could to the longer, so that the Tube now was shap'd like an inverted Syphon with leggs of a very unequal length. This Tube, notwithstanding its inconvenient figure, we made a shift, (for 'tis not easily done) to fill with Mercury, when 'twas in an inclin'd

posture, and then erecting it, the Mercury ſubſided in the longer legg, as in the *Torricellian* Experiment, and attain'd to between two foot and a quarter and two foot and an half above the ſurface of the Mercury in the ſhorter legg, which in this Inſtrument anſwers to the ſtagnant Mercury in an ordinary *Barometer*, from which to diſtinguiſh it I have elſwhere call'd this Syphon, furniſh'd with Mercury, a *Travelling Baroſcope*, becauſe it may be ſafely carried from place to place. Out of the ſhorter legg of this Tube we warily took as much Mercury as was thought convenient for what we had further to do, and this we did by ſuch a way as to hinder any Air from getting into the deſerted cavity of the longer legg, by which means the Mercurial Cylinder, (eſtimated as I lately mention'd) retain'd the ſame height above the ſtagnant Mercury in the ſhorter: The upper and clos'd part of this Travelling Baroſcope you will eaſily grant to have been free from Common

Air,

Air, not only for other Reasons that have been given elsewhere, but particularly for this, that, if you gently incline the Instrument, the Quick-silver will ascend to the top of the Tube, which you know it could not do, if the place, formerly deserted by it, were possest by the Air, which by its Spring would hinder the ascension of the Mercury, (as is easie to be tryed.) The Instrument having been thus fitted, I caus'd one of the by-standers to suck at the shorter legg, whereupon (as I expected) there presently ensued an Ascension of four or five Inches of Mercury in that legg, and a proportionable Subsidence of the Mercury in the longer, and yet in this case the raising of the Mercury cannot be pretended to proceed from the pressure of the Air. For, the weight of the Atmosphere is fenc'd off by that, which closes the upper end of the longer Tube, and the Spring of the Air has here nothing to do, since, as we have lately shewn, the space deserted by the Mercury is

not poſſeſt by the included Air, and the pulſion or condenſation of the Air, ſuppos'd by divers modern Philoſophers to be made by the dilatation of the Suckers Cheſt, and to preſs upon the ſurface of the Liquors that are to be ſuck'd up; this, *I ſay*, cannot here be pretended in regard the ſurface of the Liquor in the longer legg is every way fenc'd from the preſſure of the ambient Air. So that it remains, that the Cauſe, which rais'd the Quickſilver in the ſhorter legg upon the newly recited Suction, was the weight of the collaterally ſuperiour Quickſilver in the longer legg, which, being (at the beginning of the Suction) equivalent to the weight of the Atmoſphere, there is a plain reaſon, why the ſtagnant Mercury in the ſhorter legg ſhould be rais'd ſome Inches by Suction, as Mercury ſtagnant in an open Veſſel will be rais'd by the weight of the Atmoſphere, when the Suction is made in the open Air. For, in both caſes there is a Pipe, that reaches to the ſtagnant Mercury,

Mercury, and a competent weight to impel it into that Pipe, when the Air in the cavity of the Pipe has its Spring weaken'd by the dilatation that accompanied Suction.

The *Second* point formerly propos'd, which is, *That the weight of the Air is sufficient to raise Liquors in Suction*; may not be ill prov'd by Arguments legitimately drawn from the *Torricellian* Experiment it self, and much more clearly by the first and fifteenth of our *Continued Physico-Mechanical Experiments*. And therefore I shall only here take notice of a Phænomenon, that may be exhibited by the *Travelling Baroscope*, which, though it be much inferiour to the Experiments newly referr'd to, may be of some use on the present occasion.

Having then provided an Instrument like the *Travelling Baroscope*, mention'd under the former Head, but whose leggs were not so unequally long, and having in it made the *Torricellian* Experiment after the manner lately describ'd, we order'd the matter

ter ſo, that there remain'd in the ſhorter legg the length of divers Inches unfill'd with ſtagnant Mercury. Then I caus'd one, vers'd in what he was to do, ſo to raiſe the Quick-ſilver by Suction to the open orifice of the ſhorter legg; that, the orifice being ſeaſonably and dexterouſly cloſed, the Mercury continued to fill that legg, as long as we thought fit; and then having put a mark to the ſurface of the Mercury in the longer legg, we unſtopp'd the orifice of the ſhorter; whereupon the Mercury, that before fill'd it, was *depreſs'd*, till the ſame Liquor in the longer legg was rais'd five Inches or more above the mark, and continu'd at that height. I ſaid, that the Mercury that had been raiſed by Suction, was *depreſs'd*, rather than that it *ſubſided*, becauſe its own weight could not here make it fall, ſince a Mercurial Cylinder of five Inches was far from being able to raiſe ſo tall a Cylinder of Mercury as made a counterpoiſe in the longer legg; and therefore the depreſſion we ſpeak

of,

of, is to be referr'd to the gravitation of the Atmospherical Air upon the surface of the Mercury in the shorter legg: And I see no cause to doubt but that, if we could have procured an Instrument, into whose shorter legg a Mercurial Cylinder of many Inches higher could have been suck'd up, it would by this contrivance have appear'd, that the pressure of the Atmosphere would easily impel up a far taller Cylinder of Mercury than it did in our recited Experiment.

That this is no groundless conjecture may appear probable by the Experiment you will presently meet with. For if the gravity of an incumbent Pillar of the Atmosphere be able to compress a parcel of included Air as much as a Mercurial Cylinder, equivalent in weight to between thirty and five and thirty foot of water, is able to condense it, it cannot well be denied that the same Atmospherical Cylinder may be able by its weight to raise and counter-

ballance

ballance eight or nine and twenty Inches of Quickſilver, or an equivalent pillar of water in Tubes, where the reſiſtance of theſe two Liquors to be rais'd and ſuſtain'd by the Air, depends only upon their own unaſſiſted gravity.

To confirm our Doctrine of the Gravitation of the Atmoſphere upon the ſurface of the Liquors expos'd to it, I will ſubjoin an Experiment, that I devis'd to ſhew, that the incumbent Air, in its natural or uſual ſtate, would compreſs other Air not rarified, but in the like natural ſtate, as much as a Cylinder of eight or nine and twenty Inches of Mercury would condenſe or compreſs it.

In order to the making of this, I muſt put you in mind of what I have ſhewn elſewhere at large, and ſhall further confirm by one of the Experiments that follows the next; namely, that about twenty nine or thirty Inches of Quickſilver

See the Authors Defence of the Doctrine touching the Spring and Weight of the Air, againſt Fr. Linus, *chap* 5.

will compreſs Air, that being in its natural or uſual ſtate (as to rarity and denſity) has been ſhut up in the ſhorter legg of our Travelling or Syphon-like Baroſcope, into half the room that included Air poſſeſs'd before. This premis'd, I paſs on to my Experiment, which was this:

We provided a *Travelling Baroſcope*, wherein the Mercury in the longer legg was kept ſuſpended by the counterpoiſe of the Air that gravitated on the ſurface of the Mercury in the ſhorter legg, which we had ſo order'd, that it reached not by about two Inches to the top of the ſhorter legg. Then making a mark at the place where the ſtagnant Mercury reſted, 'twas manifeſt according to our *Hypotheſis*, that the Air in the upper part of the ſhorter legg was in its natural ſtate, or of the ſame degree of denſity with the outward Air, with which it freely communicated at the open orifice of the ſhorter legg; ſo that this ſtagnant Air was equally preſt upon by the weight

of

of the collaterally ſuperiour Cylinder of Mercury in the longer legg, and the equivalent weight of a directly incumbent pillar of the Atmoſphere. Things being in this poſture, the upper part of the ſhorter legg, which had been before purpoſely drawn out to an almoſt capillary ſmallneſs, was Hermetically ſeal'd, which, though the Inſtrument was kept erected, was ſo nimbly done by reaſon of the ſlenderneſs of the Pipe, that the included Air did not appear to be ſenſibly heated, though for greater caution we ſtaid a while from proceeding, that, if any rarefaction had been produc'd in the Air, it might have time to loſe it again. This done, we open'd the lower end of the longer legg, (which had been ſo order'd before, that we could eaſily do it, and without concuſſion of the Veſſel,) by which means the Atmoſpherical Air, gaining acceſs to the Mercury included in the longer legg, did, as I expected, by its gravitation upon it ſo compreſs the Air included in

the ſhorter legg, that, according to the eſtimate we made with the help of a Ruler, (for by reaſon of the conical figure of the upper part of the glaſs we could not take preciſe meaſures,) it was thruſt into near half the room it took up before, and conſequently, according to what I put you lately in mind of, endur'd a compreſſion like that, which a Mercurial Cylinder of about twenty nine Inches would have given it.

This Experiment, as to the main of it, was for greater caution made the ſecond time with much the like ſucceſs; and though it had been more eaſie to meaſure the Condenſation of the Air, if, inſtead of drawing out and ſealing up the ſhorter legg of the Inſtrument, we had contented our ſelves to cloſe it ſome other way; yet we rather choſe to imploy *Hermes*'s Seal, leſt, if any other courſe had been taken, it might be pretended, that ſome of the included Air, when it began to be compreſt, might eſcape out at the not perfectly and ſtrongly clos'd

clos'd orifice of the legg wherein 'twas impriſon'd.

To make it yet further appear, how much the Aſcenſion of Liquors by Suction depends upon Preſſure, rather than upon Natures imaginary Abhorrence of a *Vacuum*, or the propagated Pulſion of the Air; I will ſubjoin an *Inſtance*, wherein that preſum'd Abhorrence cannot be pretended. The Experiment was thus made:

A Glaſs-Syphon, like thoſe lately deſcrib'd, with one legg far longer than the other, was Hermetically ſeal'd at the ſhorter legg, and then by degrees there was put in, at the orifice of the longer legg, as much Quick-ſilver as by its weight ſuffic'd to compreſs the Air in the ſhorter legg into about half the room it poſſeſs'd before; ſo that, according to the *Peripatetick* Doctrine, the Air muſt be in a ſtate of preternatural Condenſation, and that to a far greater degree, than (as I have tryed) 'tis uſually brought to by Cold, intenſe enough to freeze water. Then meaſuring

the heighth of the Quickſilver in the longer Tube above the ſuperficies of that in the ſhorter, we found it not exceed thirty Inches. Now, if Liquors did riſe in Suction *ob fugam vacui*, there is no reaſon, why this Quickſilver in the longer part of the Syphon ſhould not eaſily aſcend upon Suction, at leaſt 'till the Air in the ſhorter legg had regain'd its former Dimenſions, ſince it cannot in this place be pretended, that, if the Mercury ſhould aſcend, there would be any danger of a *Vacuum* in the ſhorter legg of the Tube, in regard that the contiguous included Air is ready at hand to ſucceed as faſt as the Mercury ſubſides in the ſhorter legg of the Syphon. Nor can it be pretended, that, to fill the place deſerted by the Quickſilver, the included Air muſt ſuffer a preternatural rarefaction or diſcenſion; ſince 'tis plain in our caſe, that on the contrary, as long as the Air continues in the ſtate whereto the weight of the Quickſilver has reduc'd it, it is kept in a violent ſtate

of

of compreſſion; ſince in the ſhorter legg it was in its natural ſtate, when the Mercury, poured into the longer legg, did by its weight thruſt it into about half the room it took up before. And yet, having caus'd ſeveral perſons, one of them vers'd in ſucking, to ſuck divers times as ſtrongly as they could, they were neither of them able, not ſo much as for a minute of an hour, to raiſe the Mercury in the longer legg, and make it ſubſide in the ſhorter for more than about an Inch at moſt. And yet to ſhew you, that the Experiment was not favourably tryed for me, the height of the Mercurial Cylinder in the longer legg above the ſurface of that in the ſhorter legg was, when the Suction was tryed, an Inch or two ſhorter than thirty Inches, and the compreſt Air in the ſhorter legg was ſo far from having been by the exſuction expanded beyond its natural and firſt dimenſions, that it did not, when the contiguous Mercury ſtood as low as we could

make it ſubſide, regain ſo much as one half of the ſpace it had loſt by the precedent Compreſſion, and conſequently was in a preternatural ſtate of condenſation, when it had been freed from that ſtate as far as Suction would do it. Whence it ſeems evident, that 'twas not *ob fugam vacui*, that the Quickſilver did upon Suction aſcend one Inch; for, upon the ſame ſcore it ought to have aſcended two, or perhaps more Inches, ſince there was no danger, that by ſuch an aſcenſion any *Vacuum* ſhould be produc'd or left in the ſhorter legg of the Syphon; whereas, according to our *Hypotheſis*, a clear cauſe of the Phænomenon is aſſignable. For, before the Suction was begun, there was an *Æquilibrium* or equipollency between the weight of the ſuperiour Quickſilver in the longer legg, and a Spring of the compreſt Air included in the ſhorter legg: But when the Experimentor began to ſuck, his Cheſt being widen'd, part of the Air included in the upper part of the

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longer legg paſs'd into it, and that which remain'd had by that expanſion its preſſure ſo weaken'd, that the Air in the ſhorter legg, finding no longer the former reſiſtance, was able by its own Spring to expand it ſelf, and conſequently to depreſs the contiguous Mercury in the ſame ſhorter legg, and raiſe it as much in the longer.

But here a *Hydroſtatician*, that heedfully marks this Experiment, may diſcern a difficulty, that may perhaps ſomewhat perplex him, and ſeems to overthrow our Explication of the Phænomenon. For he may object, that if the compreſt Air in the ſhorter legg had a Spring equipollent to the weight of the Mercury in the longer legg, it appears not, why the Mercury ſhould not be ſuckt up in this Inſtrument, as well as in the free Air; ſince, according to me, the preſſure of the included Air upon the ſubjacent Mercury muſt be equivalent to the weight of the Atmoſphere, and yet experience ſhews, that the

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weight of the Atmoſphere will, upon Suction, raiſe Quickſilver to the height of ſeveral Inches.

To clear this difficulty, and ſhew, that, though it be conſiderable, 'tis not at all inſuperable, be pleaſed to conſider with me, that I make indeed the *Spring* of the compreſt Air to be equipollent to the *weight* of the compreſſing Mercury, and I have a manifeſt reaſon to do it; becauſe, if the Spring of the Air were not equipollent to that Weight, the Mercury muſt neceſſarily compreſs the Air farther, which 'tis granted *de facto* not to do. But then I conſider, that in our caſe there ought to be a great deal of difference between the operation of the *Spring* of the *included Air* and the *weight* of the *Atmoſphere*, after Suction has been once begun. For, the Weight of the Atmoſphere, that impels up Mercury and other Liquors, when the Suction is made in the open Air, continues ſtill the ſame, but the force or preſſure of the included Air is equal to the counterpreſſure

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of the Mercury no longer than the first moment of the Suction, after which, the force of the imprison'd Air still decreases more and more, since this compress Air, being further and further expanded, must needs have its Spring proportionably weaken'd, so that it need be no wonder, that the Mercury was not sucke up any more than we have related, for there was nothing to make it ascend to a greater height, than that, at which the debilitated Spring of the (included but) expanded Air was brought to an equipollency with the undiminish'd and indeed somewhat increas'd weight of the Mercurial Cylinder in the longer legg, and the pressure of the Aetial Cylinder in the same legg, lessen'd by the action of him that suck'd. For whereas, when the orifice of this legg stood open, the Mercury was preſt on by a Cylinder of the Atmospherical Air, equivalent to about thirty Inches of Quick-silver; by the mouth and action of him that suck'd the Tube was freed

freed from the external Air, and by the dilatation of his *Thorax*, the neighbouring Air, that had a free paſſage through his wind-pipe to it, was proportionably expanded, and had its Spring and preſſure weaken'd: By which means, the compreſt Air in the ſhorter legg of the Syphon was inabled to impel up the Mercury, 'till the lately mention'd *Equilibrium* or equipollency was attain'd. And I muſt here take notice, that, as the Quickſilver was rais'd by Suction but a little way, ſo the Cylinder that was rais'd was a very long one; whereas, when Mercury is ſuck'd up in the free Air, it is ſeldom rais'd to half that length; though, as I noted before, the impellent cauſe, which is the weight of the Atmoſphere, continued ſtill the ſame, whereas in our Syphon, when the Mercury was ſuck'd up but an Inch, the compreſt Air, poſſeſſing double the ſpace it did before, had by this expanſion already loſt a very conſiderable part of its former Spring and Preſſure.

I ſhould here conclude this Diſcourſe, but that I remember a *Phænomenon* of our Pneumatic Engin, which to divers Learned Men, eſpecially *Ariſtotelians*, ſeem'd ſo much to argue, that Suction is made either by a *Fuga Vacui*, or ſome internal Principle, that divers years ago I thought fit to ſet down another account of it, and lately meeting with that account among other papers, I ſhall ſubjoin it juſt as I found it, by way of *Appendix* to the foregoing Tract.

Among the more familiar *Phænomena* of the *Machina Boyliana*, (as they now call it,) none leaves ſo much ſcruple in the Minds of ſome ſorts of Men, as this, That, when ones finger is laid cloſe upon the orifice of the little Pipe, by which the Air is wont to paſs from the Receiver into the exhauſted Cylinder, the pulp of the finger is made to enter a good way into the cavity of the Pipe, which doth not happen without a conſiderable ſenſe of pain in the lower part

part of the finger. For most of those that are strangers to *Hydrostaticks*, especially if they be prepossess'd with the Opinions generally receiv'd both in the *Peripatetick* and other Schools, perswade themselves, that they feel the newly mention'd and painful protuberance of the pulp of the finger, to be effected not by pressure, as we would have it, but distinctly by Attraction.

To this we are wont to answer, That common Air being a Body not devoid of weight, the Phenomenon is clearly explicable by the pressure of it: For, when the finger is first laid upon the orifice of the Pipe, no pain nor swelling is produc'd, because the Air which is in the Pipe presses as well against that part of the finger which covereth the orifice, as the ambient Air doth against the other parts of the same finger. But when by pumping, the Air in the Pipe, or the most part of it, is made to pass out of the Pipe into the exhausted Cylinder, then there is nothing left

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in the Pipe, whoſe preſſure can any thing near countervail the undiminiſh'd preſſure of the external Air on the other parts of the finger; and conſequently, that Air thruſts the moſt yielding and fleſhy part of the finger, which is the pulp, into that place where its preſſure is unreſiſted, that is, into the cavity of the Pipe, where this forcible intruſion cauſeth a pain in thoſe tender parts of the finger.

To give ſome viſible Illuſtration of what we have been ſaying, as well as for other purpoſes, I thought on the following Experiment.

We took a Glaſs-pipe of a convenient length, and open at both ends, whoſe cavity was near about an Inch in *Diameter*, (ſuch a determinate breadth being convenient, though not neceſſary:) To one of the ends of this Pipe we cauſed to be firmly tyed on a piece of very fine Bladder, that had been ruffled and oyl'd, to make it both very limber and unapt to admit water; and care was taken, that the

the piece of Bladder tyed on ſhould be large enough, not only to cover the orifice, but to hang looſe ſomewhat beneath it.

This done, we put the cover'd end of the Pipe into a Glaſs-body (or Cucurbit) purpoſely made more than ordinarily tall, and the Pipe being held in ſuch manner, as that the end of it reach'd almoſt, but not quite, to the bottom of the Glaſs-body, we cauſed water to be poured both into this Veſſel and into the Pipe (at its upper orifice, which was left open) that the water might aſcend equally enough, both without and within the Pipe. And when the Glaſs-body was full of water, and the ſame liquor was level to it, or a little higher within the Pipe, the Bladder at the lower orifice was kept plump, becauſe the water within the Pipe did by its weight preſs as forcibly downwards, as the external water in the large Glaſs endeavour'd to preſs it inwards and upwards.

All this being done, we eaus'd

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part of the water in the Pipe to be taken out of it, (which may be done either by putting in and drawing out a piece of Spunge or of Linnen, or more expeditiously by ſucking up part of the water with a ſmaller Pipe to be immediately after laid aſide,) upon which removal of part of the internal water, that which remained in the Pipe being no longer able, by reaſon of its want of weight, to preſs againſt the inſide of the Bladder near as forcibly as it did before, the external water, whoſe weight was not leſſen'd, preſs'd the ſides and bottom of the Bladder, whereto it was contiguous, into the cavity of the Pipe, and thruſted it up therein ſo ſtrongly, that the diſtended Bladder made a kind of either Thimble or Hemiſphere within the Pipe. So that here we have a protuberance, like that above-mentioned of the finger, effected by Pulſion, not Attraction; and in a caſe where there can be no juſt pretence of having recourſe to Natures Abhorrence of a

Vacuum, since, the upper orifice of the Pipe being left wide open, the Air may pass in and out without resistance.

The like swelling of the Bladder in the Pipe we could procure without taking out any of the internal liquor, by thrusting the Pipe deeper into the water; for then the external liquor, having by reason of its increase of depth a greater pressure on the outside of the Bladder, than the internal liquor had on the inside of it, the Bladder must yield to the stronger pressure, and consequently be impell'd up.

If the Bladder lying loose at the lower end of the Pipe, the upper end were carefully clos'd with ones thumb, that the upper Air might not get out until the Experimentor thought fit, and if the thus clos'd Pipe were thrust almost to the bottom of the water, the Bladder would not be protuberant inwards, as formerly; because the included Air by virtue of its Spring, resisted from within

within the preſſure of the external water againſt the outſide of the Bladder: But if the thumb, that ſtopp'd the Pipes upper orifice, were remov'd, the formerly compreſs'd Air having liberty to expand it ſelf, and its elaſticity being weaken'd thereby, the external water would with ſuddenneſs and noiſe enough, not to be unpleaſant to the Spectators, drive up the Bladder into the cavity of the Pipe, and keep it there very protuberant.

To obviate an Objection, that I foreſaw might be brought in by perſons not well vers'd in *Hydroſtaticks*, I caus'd the Pipe fore-mention'd, or ſuch another, to be ſo bent near the lower end, as that the orifice of it ſtood quite on one ſide, and the parts of the Pipe made an angle as near to a right one as he that blew it could bring it to. This lower orifice being fitted with a Bladder, and the Pipe with its contained liquor being thruſt under water after the former manner, the lateral preſſure

of the water forc'd the Bladder into the ſhort and horizontal legg, and made it protuberate there, as it had done when the Pipe was ſtraight.

Laſtly, that the Experiment might appear not to be confin'd to one liquor; inſtead of *water* we put into the unbent Pipe as much red *wine* (whoſe colour would make it conſpicuous) as was requiſit to keep the Bladder ſomewhat ſwelling outwards, when it was ſomewhat near the bottom of the water; and then 'twas manifeſt, that, according as we had foreſeen, the ſuperficies of the red liquor in the Pipe was a good deal higher than that of the external water, and if the depth of both liquors were proportionably leſſen'd, the difference of height betwixt the two ſurfaces would indeed, as it ought to happen, decreaſe, but ſtill the ſurface of the wine would be the higher of the two, becauſe being lighter in *ſpecie* than the common water, the *Æquilibrium* between the preſſures of the two liquors upon the Bladder would

would not be maintain'd, unleſs a greater height of *wine* compenſated its defect of ſpecifick gravity. And if the Pipe was thruſt deeper into the water, then the Bladder would be made protuberant inwards, as when the Pipe had water in it. By which it appears, that theſe *Phænomena*, without recourſe to *attraction*, may be explicated barely by the Laws of the *Æquilibrium* of Liquors.

FINIS.